New predictions on SHE nuclei

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1. Ground states of Z=98-126 odd and odd-odd nuclei based on the fit to masses beyond Z=82, N=126.
2. Big oblate deformations around Z=120, N=166 - landscapes & possible alpha-decay hindrance seen in HFBCS.
3. Predictions for SHE with Z>126

Microscopic-macroscopic method with a possibility of many various deformations

- $E_{tot}(\beta_{\lambda\mu}) = E_{macro}(\beta_{\lambda\mu}) + E_{micro}(\beta_{\lambda\mu})$
- Calculated energy: $E = E_{tot}(\beta_{\lambda\mu}) - E_{macro}(\beta_{\lambda\mu} = 0)$
- $E_{macro}(\beta_{\lambda\mu}) = \text{Yukawa} + \text{exponentia l}$
- $E_{micro}(\beta_{\lambda\mu}) = \text{Woods - Saxon} + \text{pairing BCS}$

Odd & odd-odd SH nuclei

- Shape parametrization:

$$R(\Theta,\Phi) = c(\{\beta\})R_0\{1+\beta_{20}Y_{20}+\beta_{40}Y_{40}+\beta_{60}Y_{60}+\beta_{80}Y_{80}\}$$

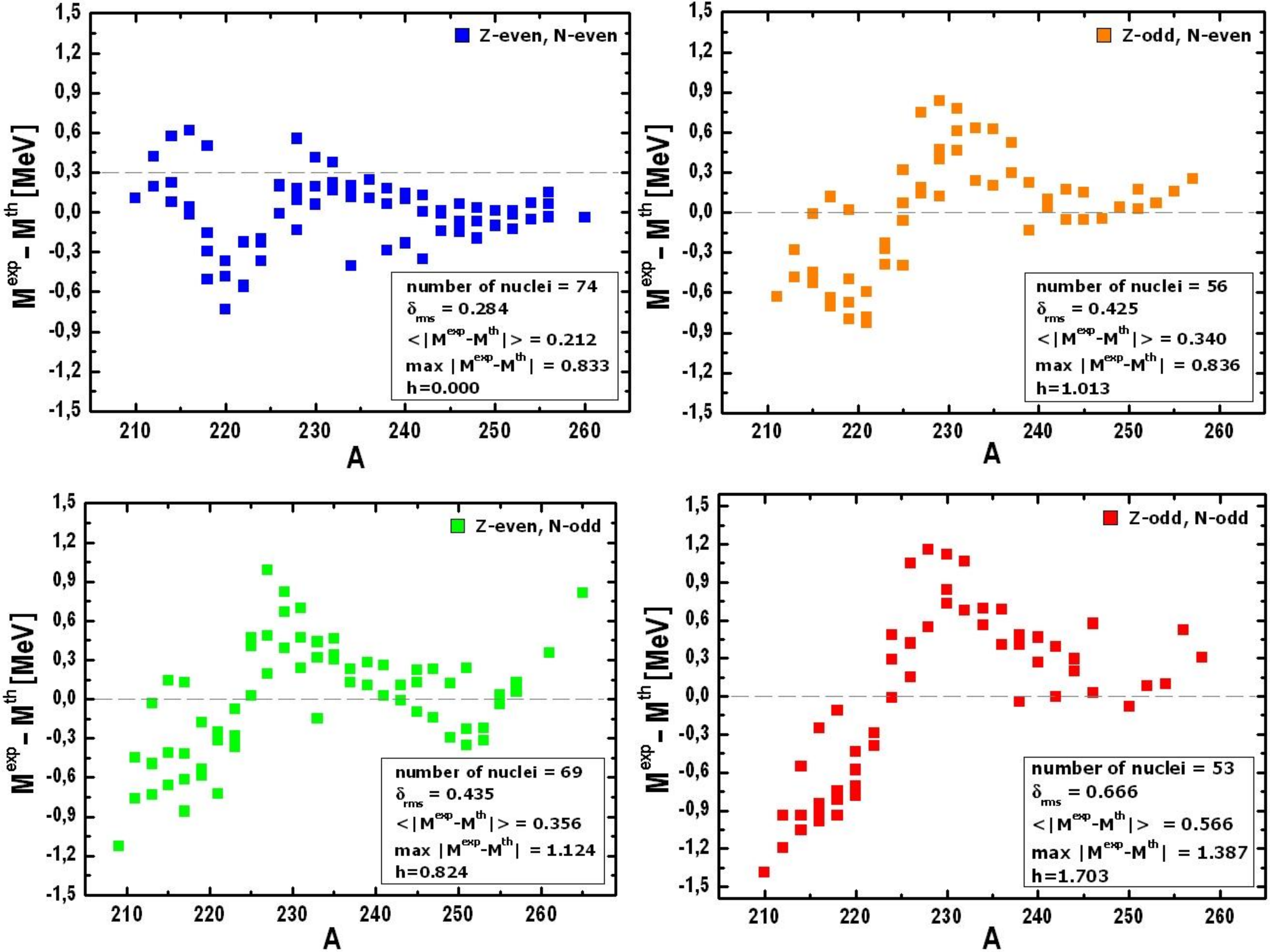
Some aspects not quite clear

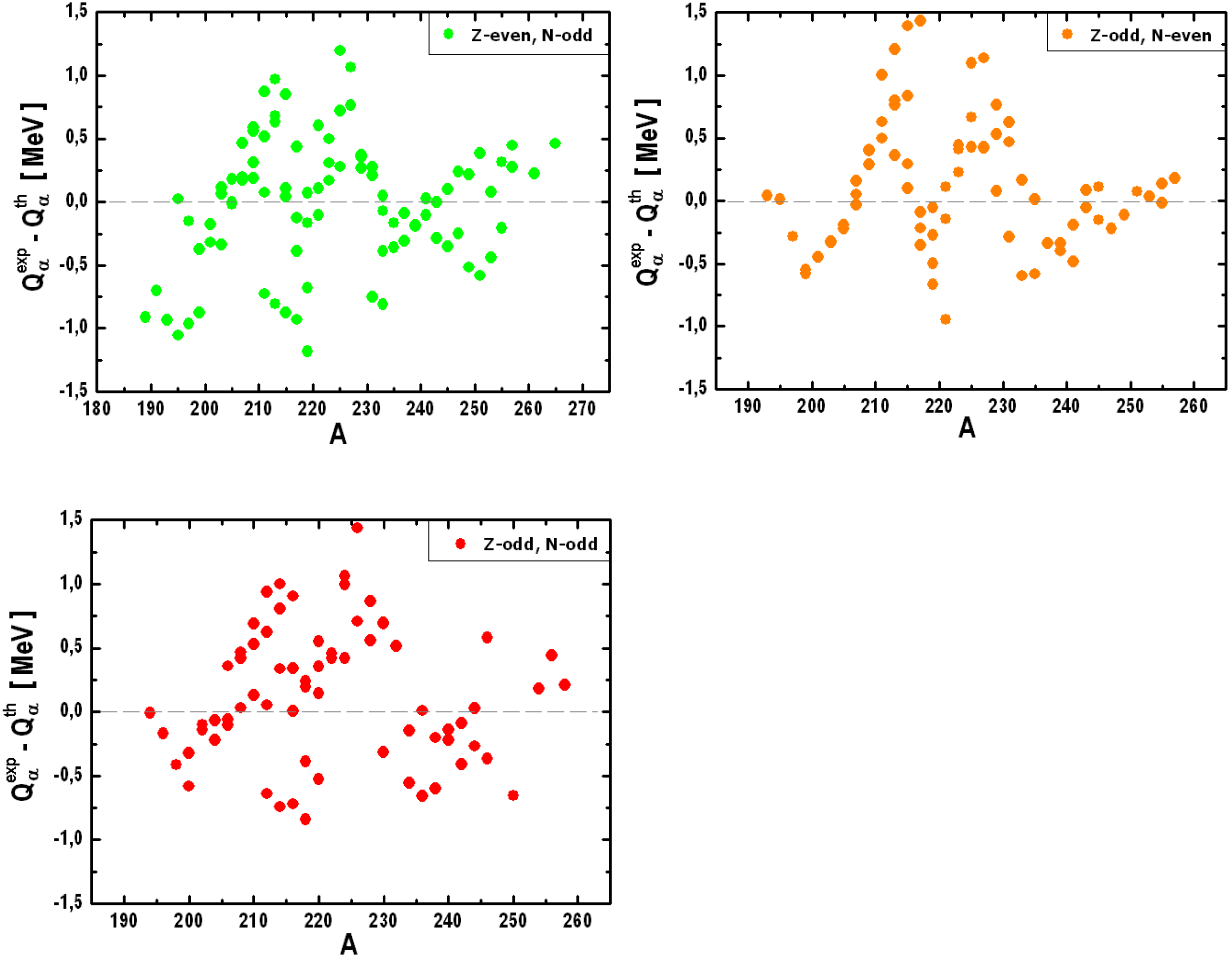
- We use blocking procedure; this causes often a sharp decrease of pairing effect.
- How to calculate barriers: adiabatic or the lowest possible?

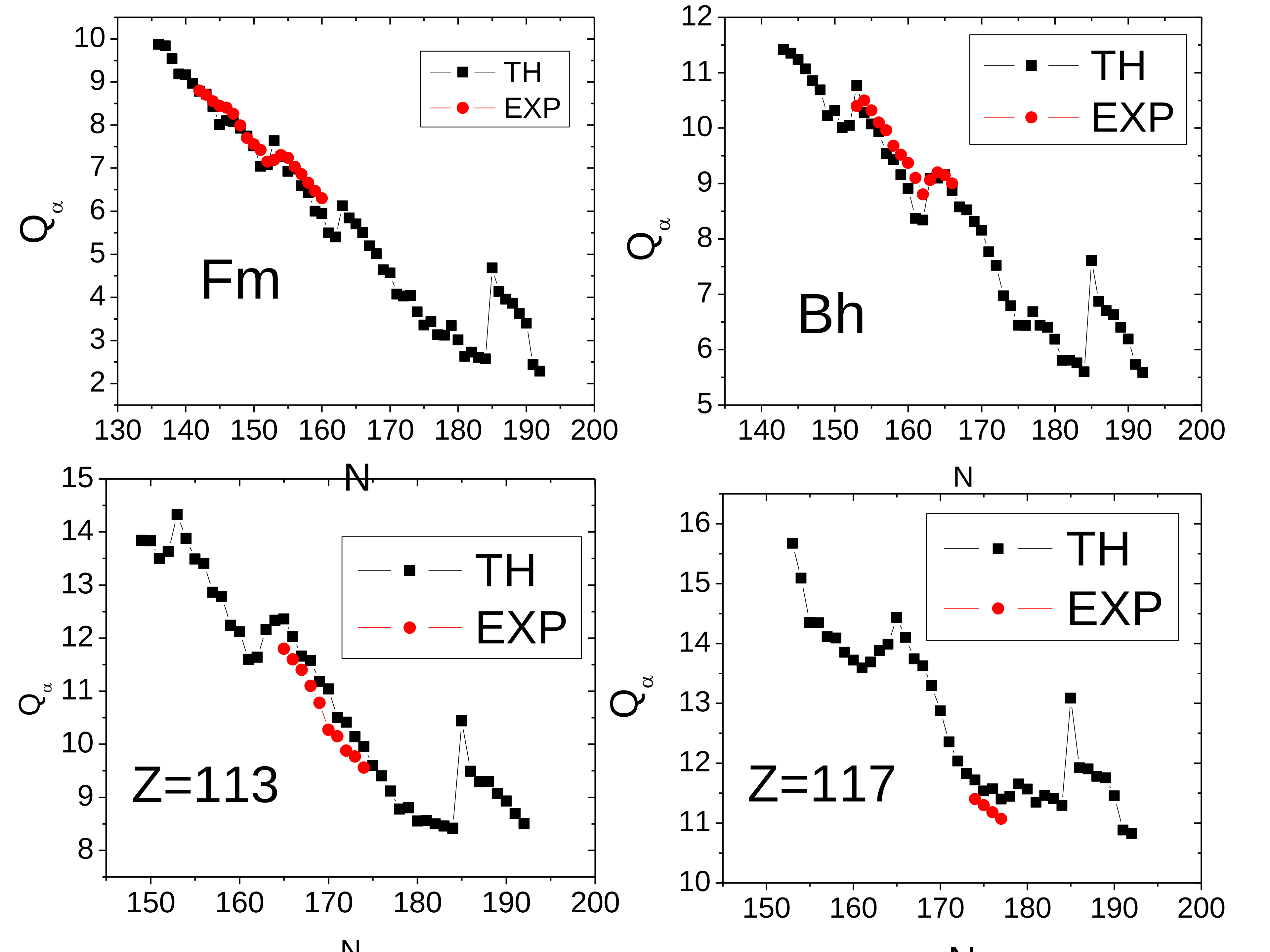
Fit to the experimental masses

- $Z>82$, $N>126$,
- Number of nuclei: 252
- For odd and odd-odd systems there are 3 additional parameters – macroscopic energy shifts.

Predictions for SHE


Z-even, N-even
number of nuclei = 74
δrms = 0.284
<|Mexp-Mth|> = 0.212
max |Mexp-Mth| = 0.833
h=0.000
Z-odd, N-even
number of nuclei = 56
δrms = 0.425
<|Mexp-Mth|> = 0.340
max |Mexp-Mth| = 0.836
h=1.013
Z-even, N-odd
number of nuclei = 69
δrms = 0.435
<|Mexp-Mth|> = 0.356
max |Mexp-Mth| = 1.124
h=0.824
Z-odd, N-odd
number of nuclei = 53
δrms = 0.666
<|Mexp-Mth|> = 0.566
max |Mexp-Mth| = 1.387
h=1.703
Mexp - Mth [MeV]
A


Z-even, N-odd
Z-odd, N-even
Z-odd, N-odd
$Q_\alpha^{exp} - Q_\alpha^{th}$ [MeV]
A
1,5
1,0
0,5
0,0
-0,5
-1,0
-1,5
180
190
200
210
220
230
240
250
260
270

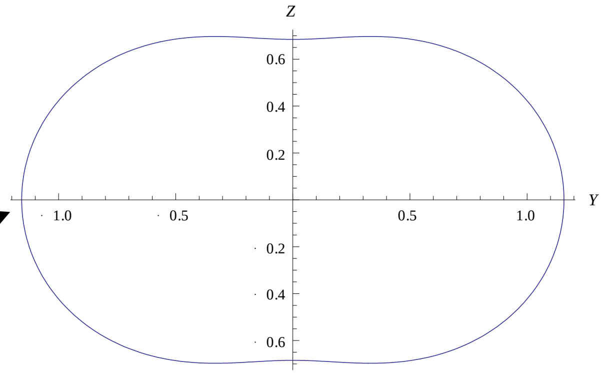

Fm
TH
EXP
Qα
N
Bh
TH
EXP
Qα
N
Z=113
TH
EXP
Qα
N
Z=117
TH
EXP
Qα
N

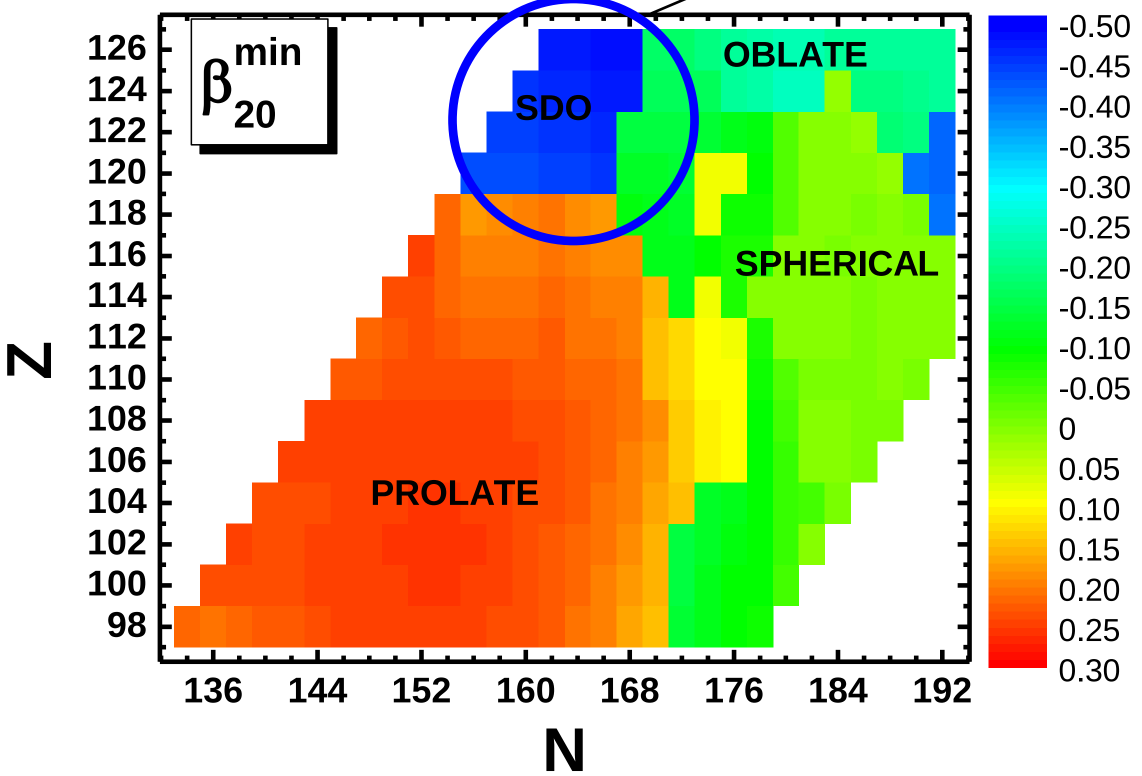
Ground state shapes, even-even

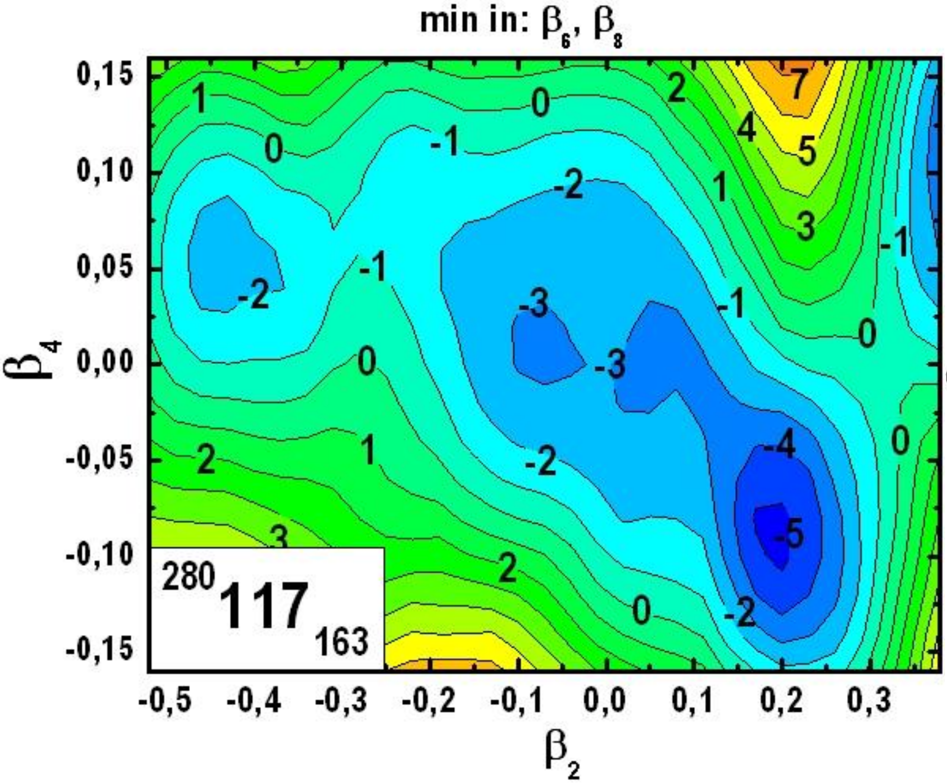
$SDO:$

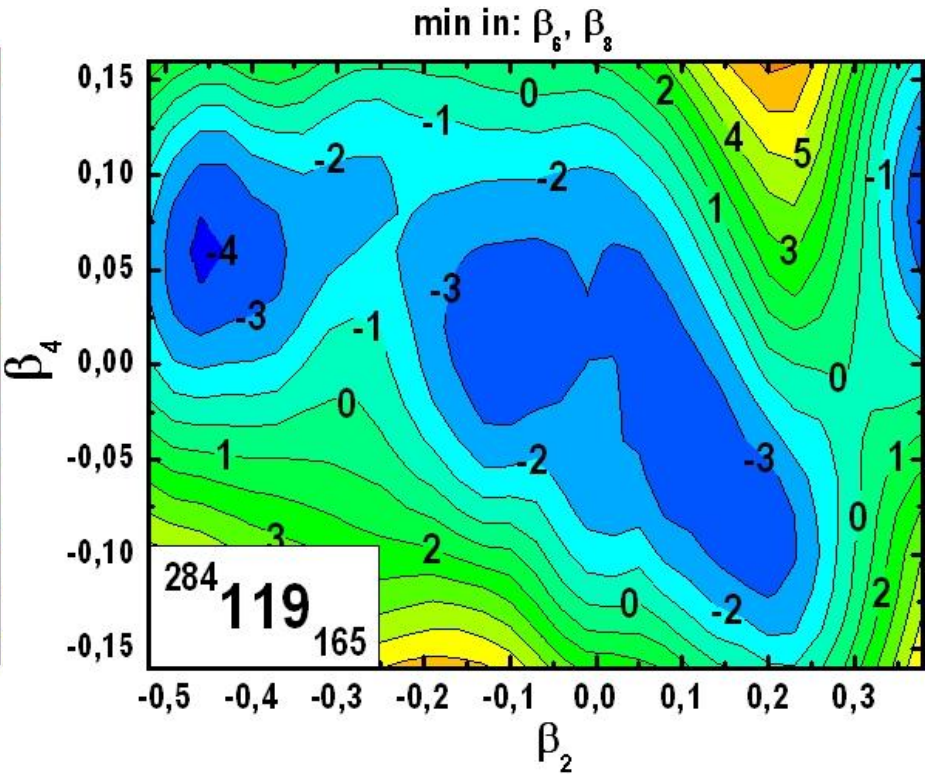
$\beta_{20} \approx -0.5$

$Axis.ratio \approx \frac{3}{2}$









Possible Q-alpha hindrance

Hartree-Fock-BCS with SLy6 force

- Features: includes 2-body c.m. correction that improves fission barriers as compared to SLy4.
- Constraints:

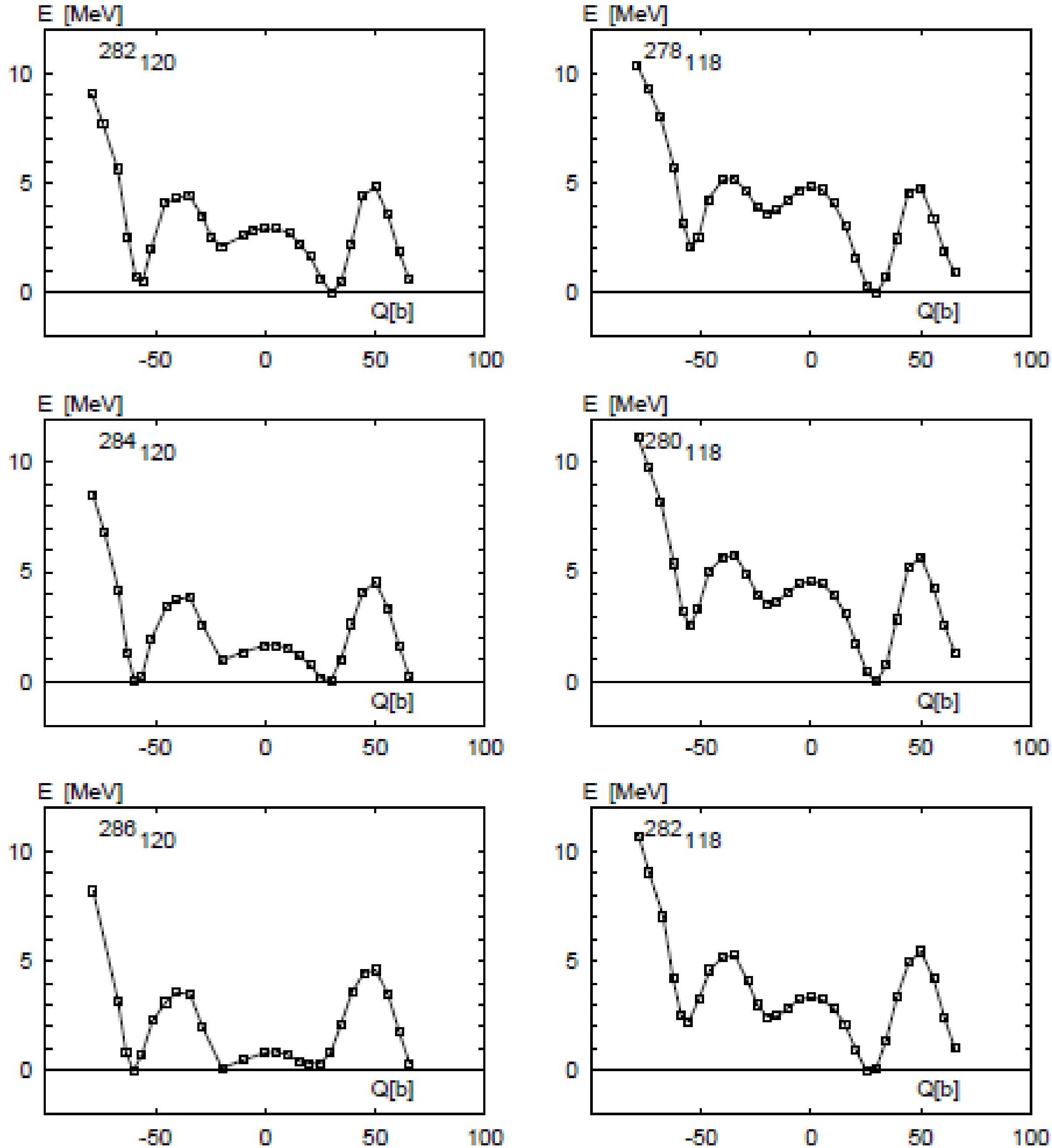
- two symmetry planes; possible one reflection asymmetry plane,

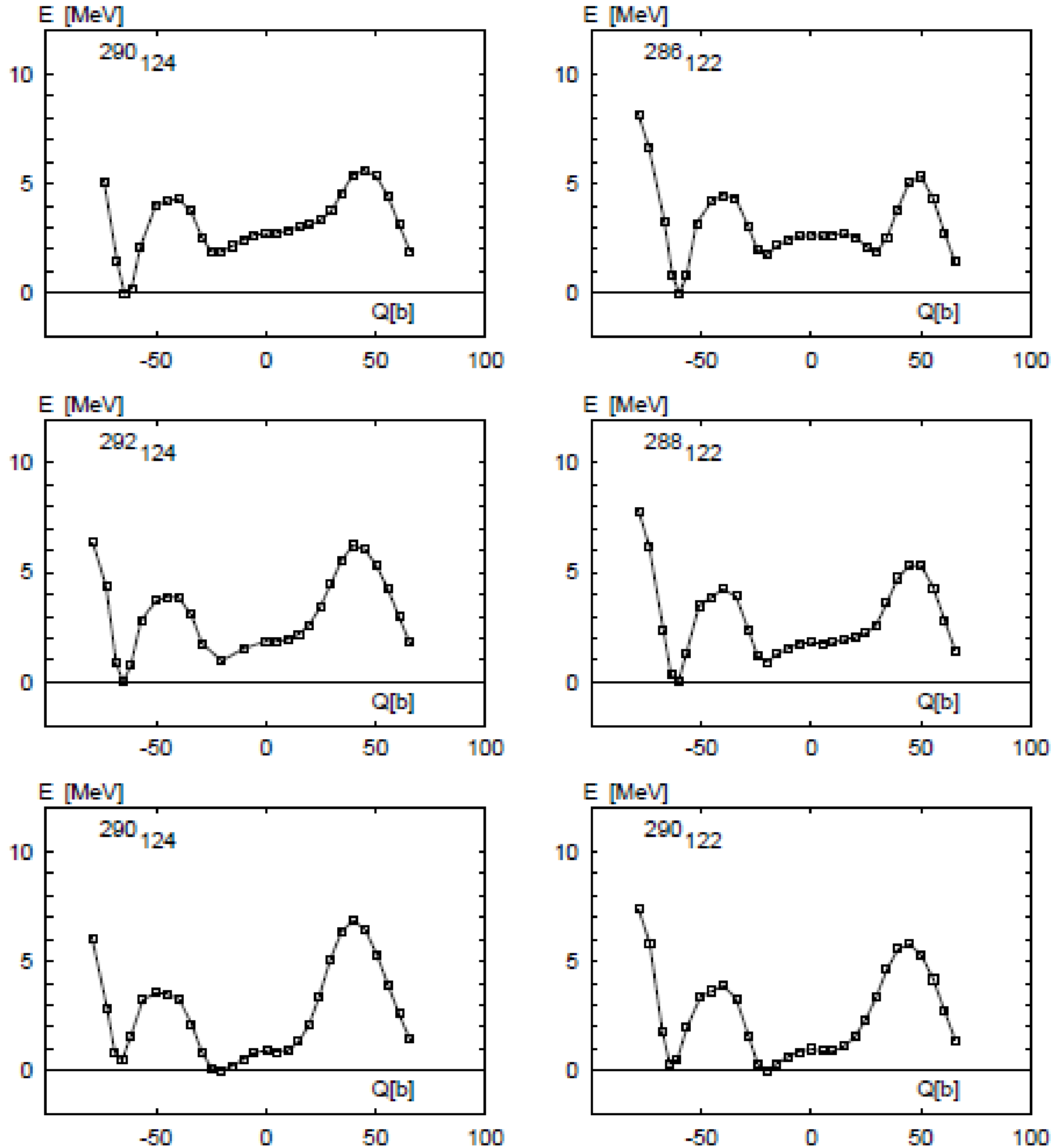
- Q_{20} & Q_{22} on the mesh, relation with the Bohr coordinates:

$$Q = \sqrt{Q_{20}^2 + 3Q_{22}^2} \qquad \beta = \sqrt{5\pi}Q/[3r_0^2 A^{5/3}]$$

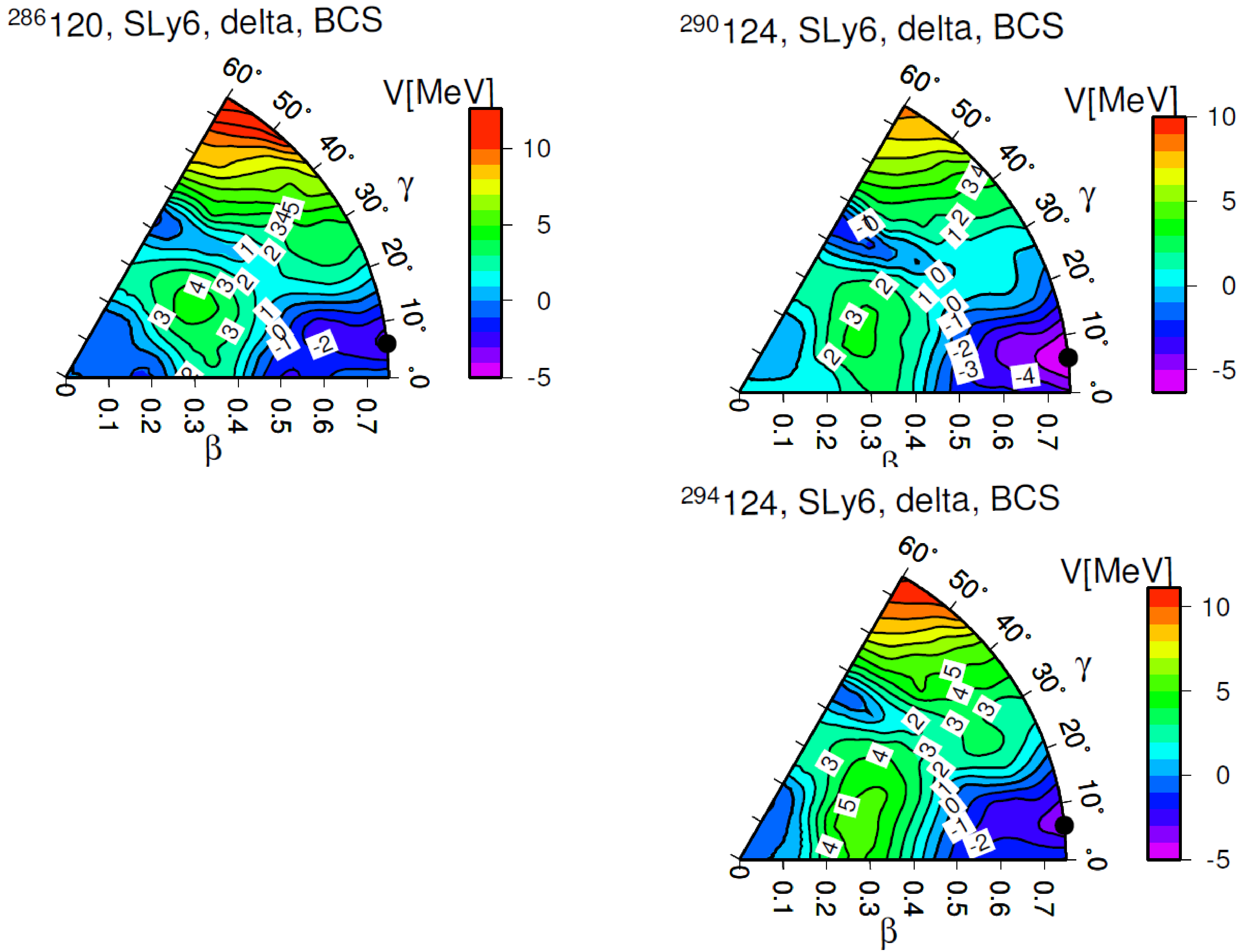
$$\tan(\gamma) = \sqrt{3}Q_{22}/Q_{20}$$

Z=120 alpha hindrance possible

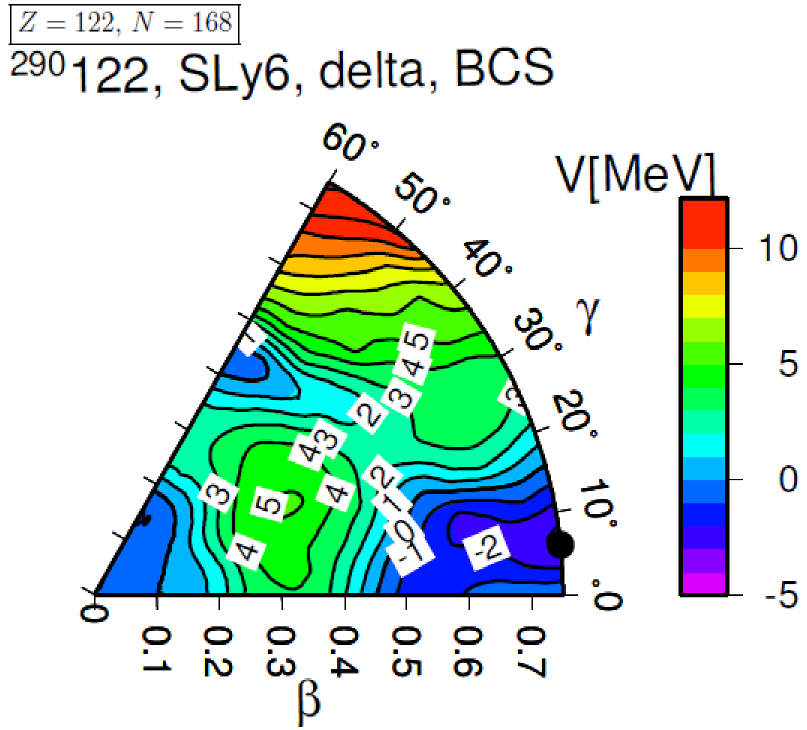


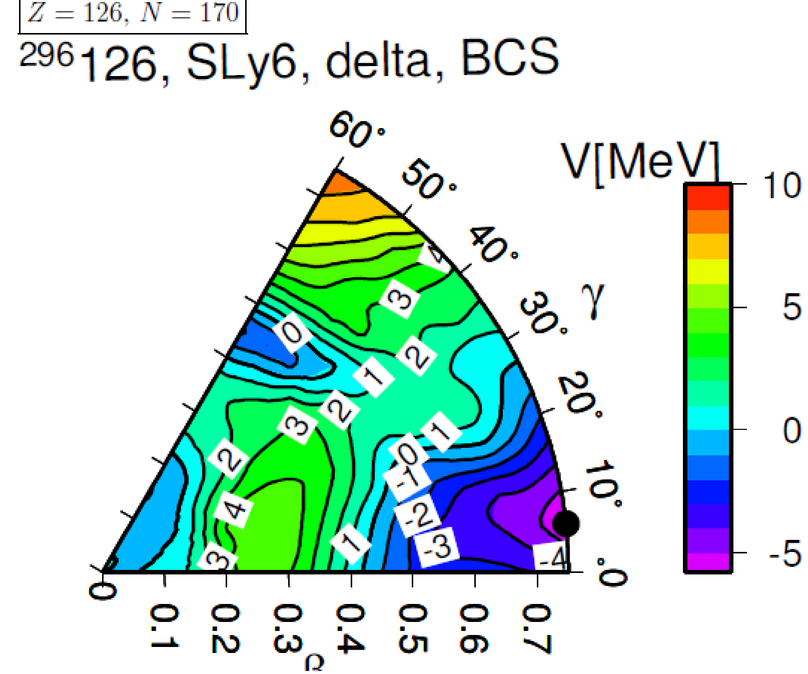


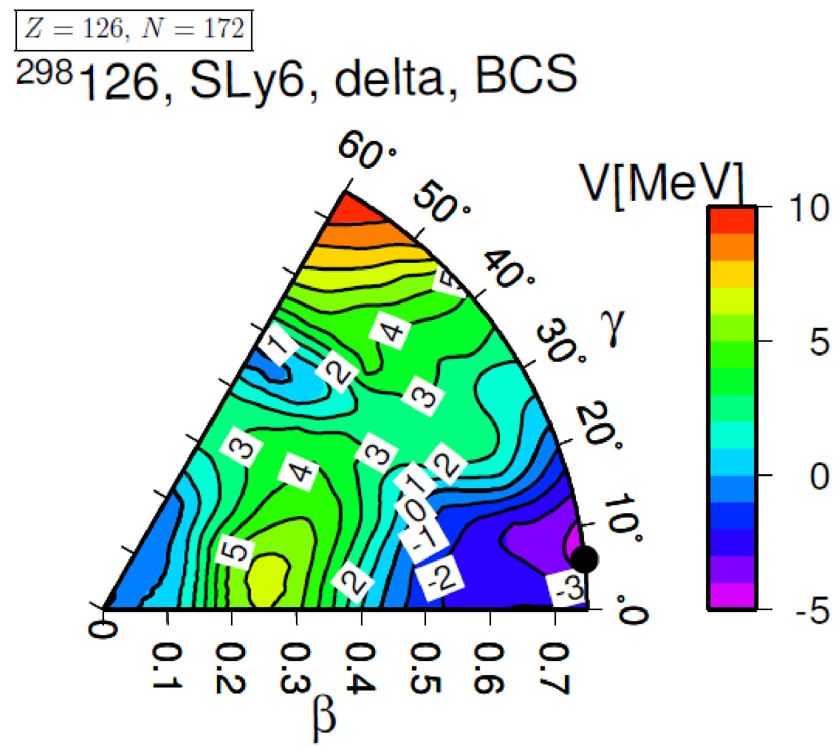
E [MeV]
290 124
Q[b]
E [MeV]
286 122
Q[b]
E [MeV]
292 124
Q[b]
E [MeV]
288 122
Q[b]
E [MeV]
290 124
Q[b]
E [MeV]
290 122
Q[b]
10
5
0
-50
0
50
100



286120, SLy6, delta, BCS
V[MeV]
γ
β
290124, SLy6, delta, BCS
V[MeV]
γ
β
294124, SLy6, delta, BCS
V[MeV]
γ
β


Z = 122, N = 168
^{290}122, SLy6, delta, BCS
V[MeV]
γ
β


Z = 126, N = 170
^{296}126, SLy6, delta, BCS
V[MeV]
γ


Z = 126, N = 172
^{298}126, SLy6, delta, BCS
V[MeV]
γ
β

Conclusions – part 1

- First results of the WS model for heavy & SH odd & odd-odd systems are worse than for the even-even species. One has to check possible refinements.
- Superdeformed oblate ground-states appear for odd nuclei within the WS model.
- HF BCS calculations reproduce SDO minima; they appear as g.s. also up to N=170.
- Structural hindrance of the Z=120 – 118 alpha-decay is probable in all models.

The aim of the work:

- to investigate the uncharted region of atomic numbers Z ≥128 and predict, which nuclei might be stable,
- to assess the role of nonaxial configurations, that turns out to be crucial for calculations of stability against fission,
- to compare the results for superheavy nuclei obtained from microscopic-macroscopic and Hartree-Fock-BCS models trying to find some common features.

Microscopic-macroscopic method

- Shape parametrization:

$$R(\Theta,\Phi) = c(\{\beta\})R_0\{1+\beta_{20}Y_{20}+\beta_{40}Y_{40}+\beta_{60}Y_{60}+\beta_{80}Y_{80}+$$
$$+\beta_{22}Y_{22}^{(+)}+\beta_{42}Y_{42}^{(+)}+\beta_{44}Y_{44}^{(+)}\}$$

- β_{20} & β_{22} on the mesh, minimalization in $\{\beta_{40}\ \beta_{60}\ \beta_{80}\ \beta_{42}\ \beta_{44}\}$.

Hartree-Fock-BCS with SLy6 force

- 180 neutron & 110 proton levels
- Pairing: delta interaction of time-reversed pairs with a smooth energy cutoff, V_n= 316 MeV fm^3 , V_p= 322 MeV fm^3

What has been done?
Preliminary results (1)

Energy landscapes for systems with Z=128-134, N=174-230 have been studied.

3 MeV and deeper minima are obtained for N≈180 and 228.

For Z=128, N≈180 4,5 MeV deep, spherical minima occur in the Skyrme SLy6 HFBCS model and 3,5 MeV oblate minima are found in the micro-macro Woods-Saxon model. These minima diminish quickly (in both models) with increasing atomic number (only 1 MeV for Z=134).

What has been done? Preliminary results (2)

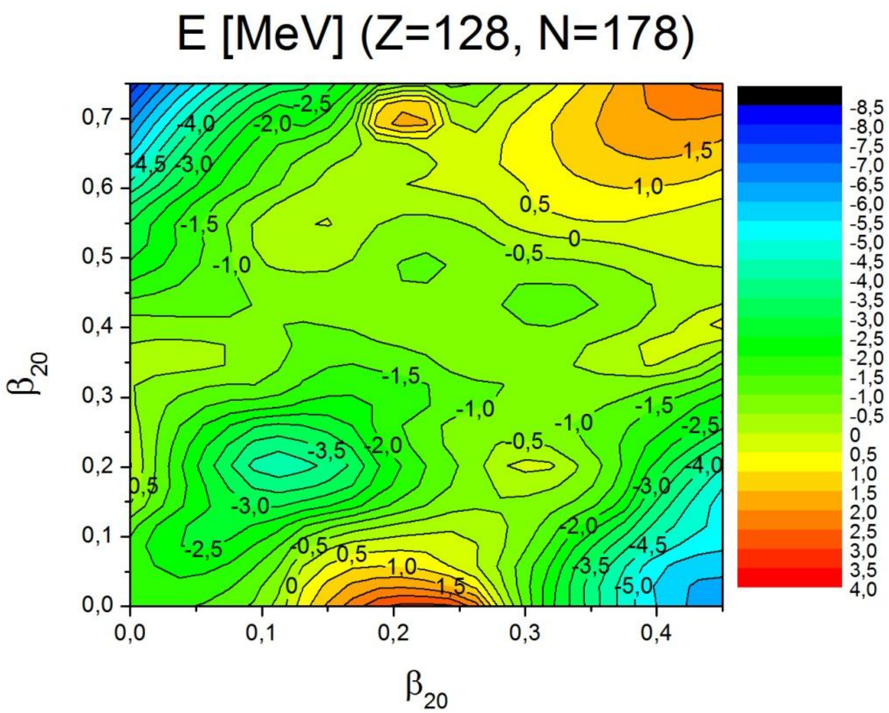
For N≈228, Z=128-134, 3 MeV deep spherical and prolate minima, and 4 MeV oblate minimum in Z=134 are obtained with the HFBCS model.

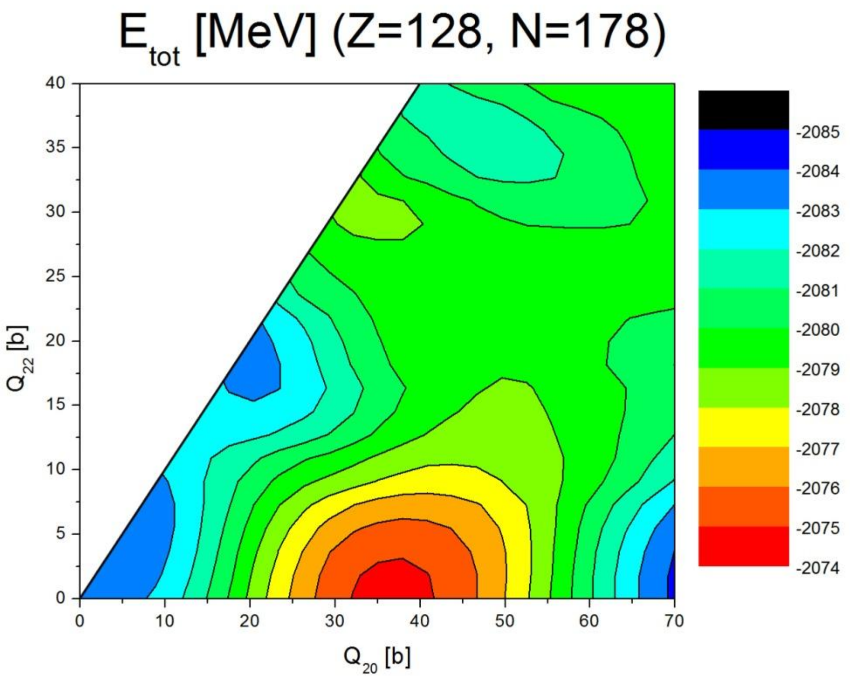
In the micro-macro model, 2,5 MeV oblate minima for Z≈134, N≈228 are found.

There is no sign of stability for intermediate neutron numbers.

Micro-macro

Hartree-Fock-BCS





Shape at minimum: oblate

Fission barrier: 3.5 MeV

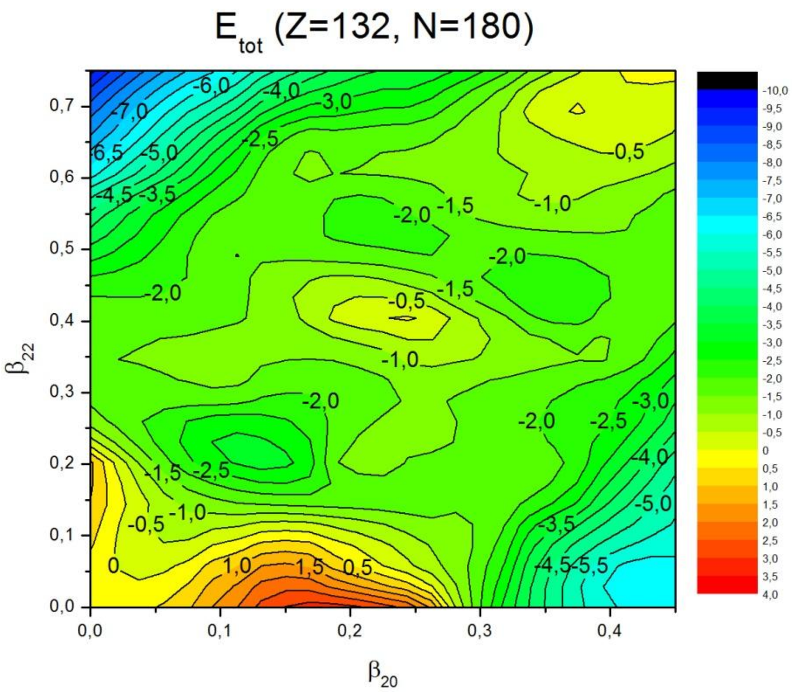
Shape at minimum: spherical

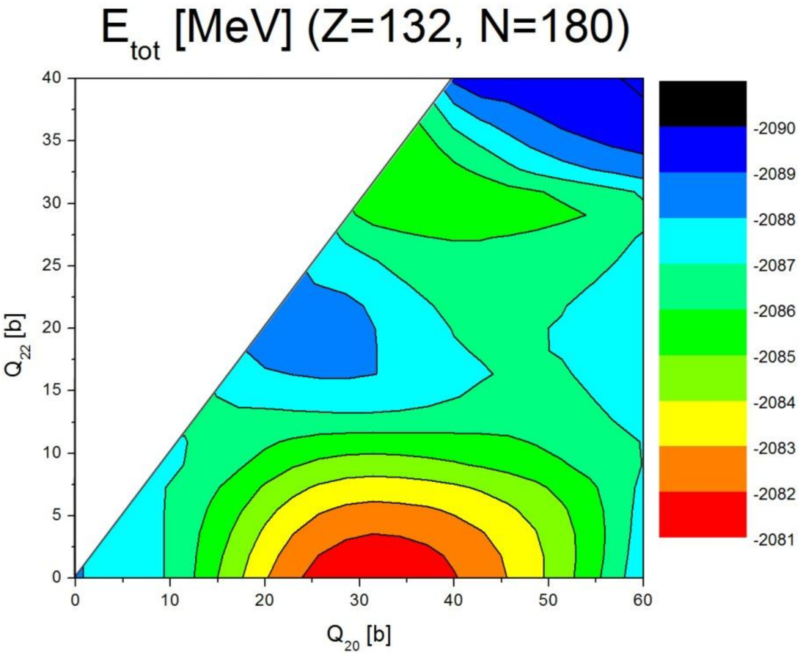
Fission barrier: 4.0 MeV

But $Q_\alpha \approx 17$ MeV !

Micro-macro

Hartree-Fock-BCS





Shape at minimum: oblate

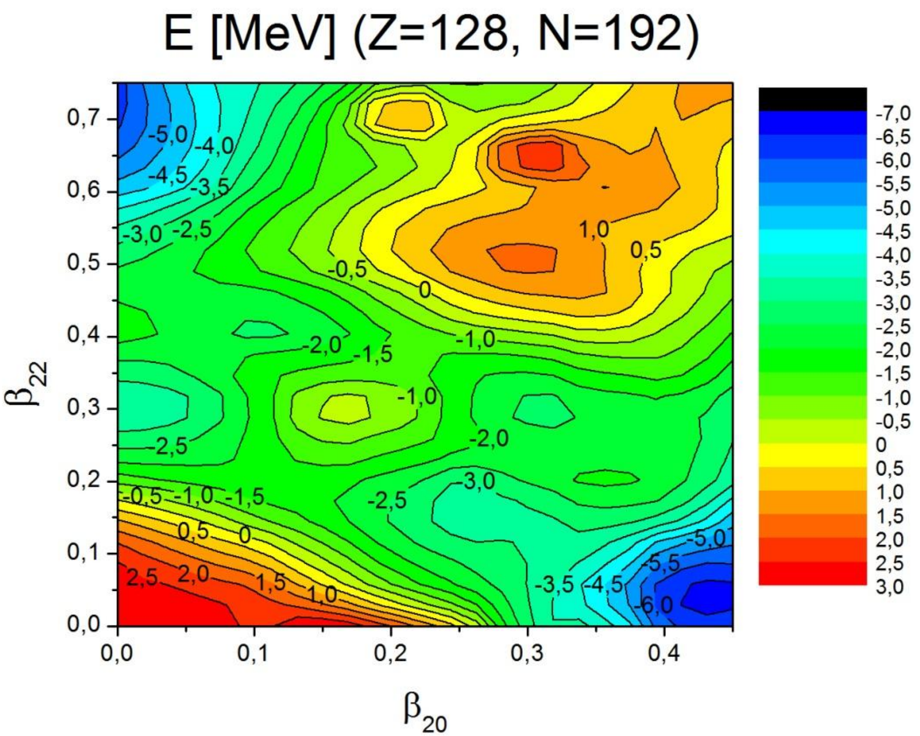
Fission barrier: 1.5 MeV

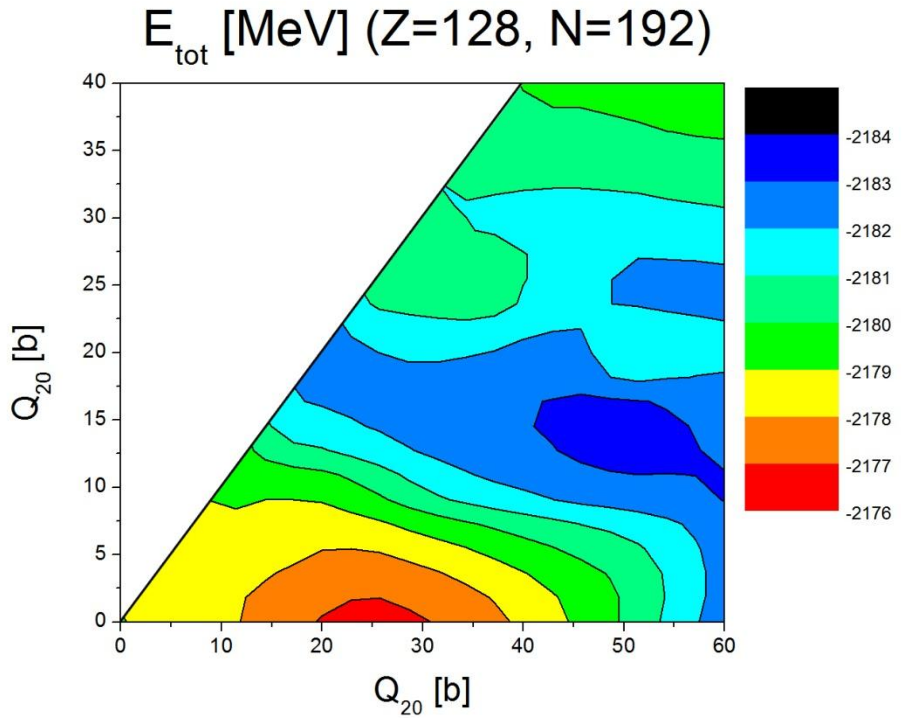
Shape at minimum: oblate

Fission barrier: 2.0 MeV

Micro-macro

Hartree-Fock-BCS



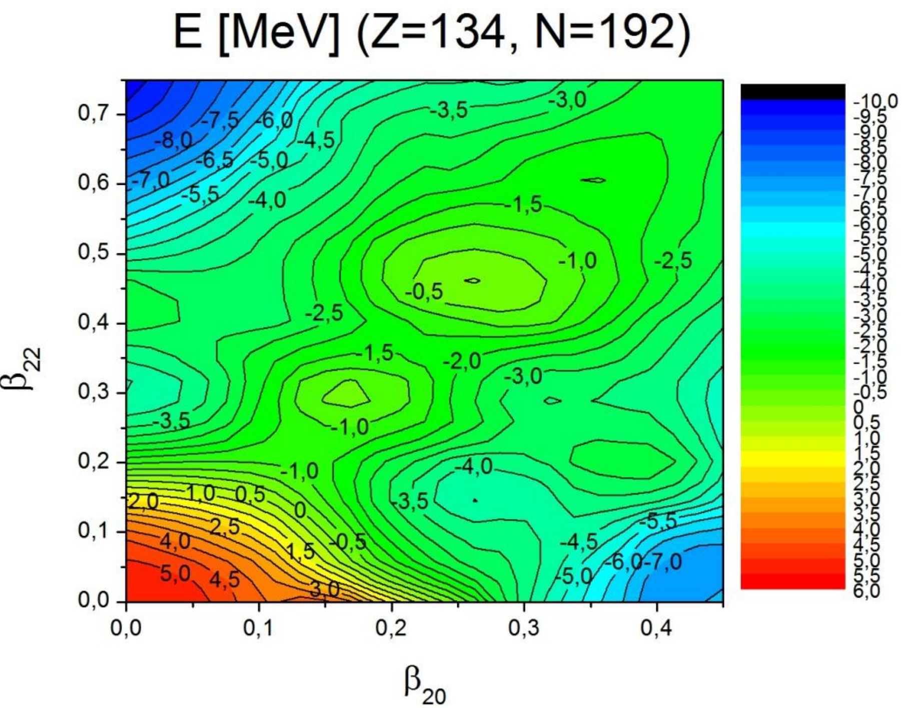
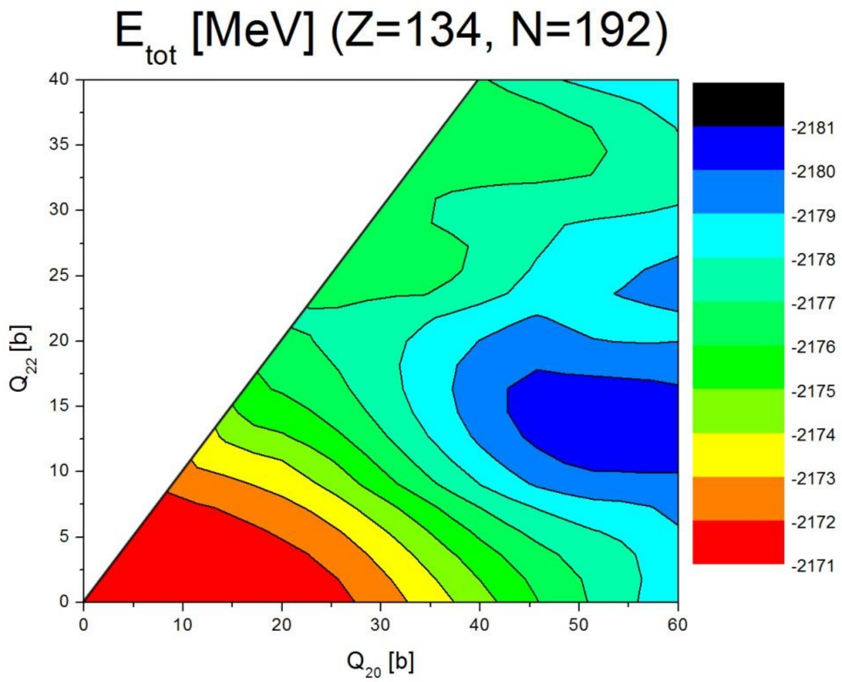


Shape at minimum: ---

Fission barrier: none

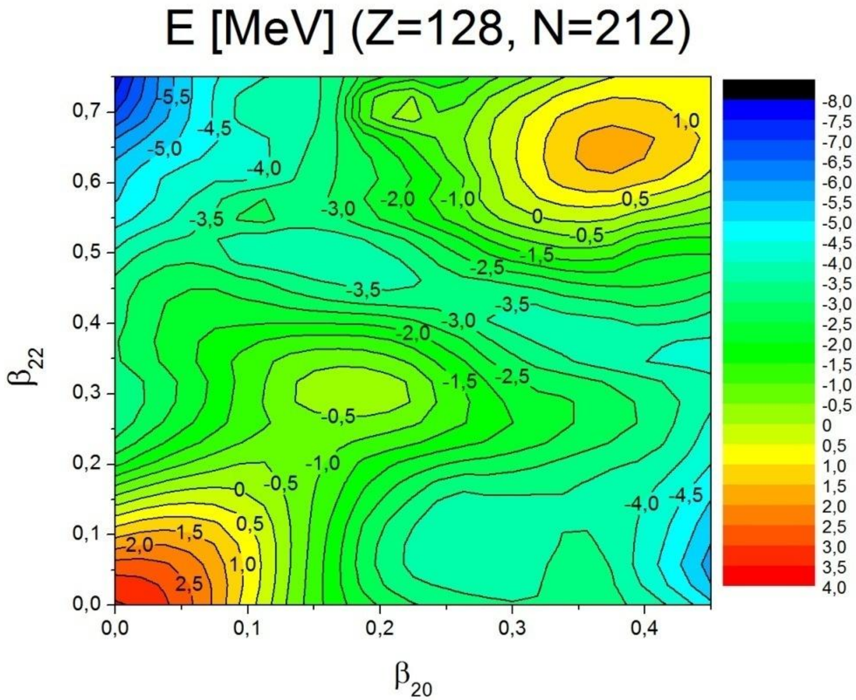
Shape at minimum: ---

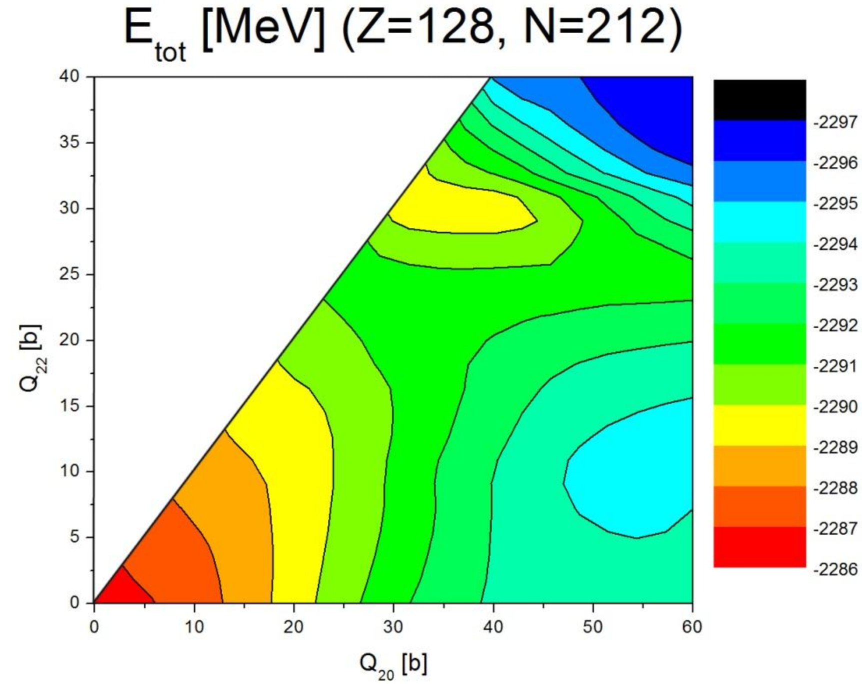
Fission barrier: none

Micro-macro	Hartree-Fock-BCS
	
Shape at minimum: ---	Shape at minimum: ---
Fission barrier: none	Fission barrier: none

Micro-macro

Hartree-Fock-BCS





Shape at minimum: ---

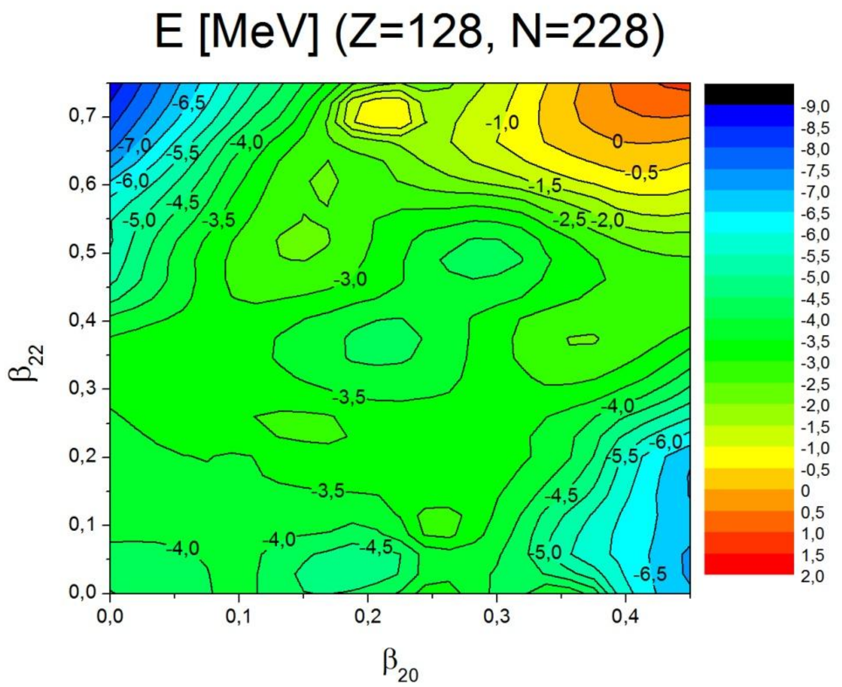
Fission barrier: none

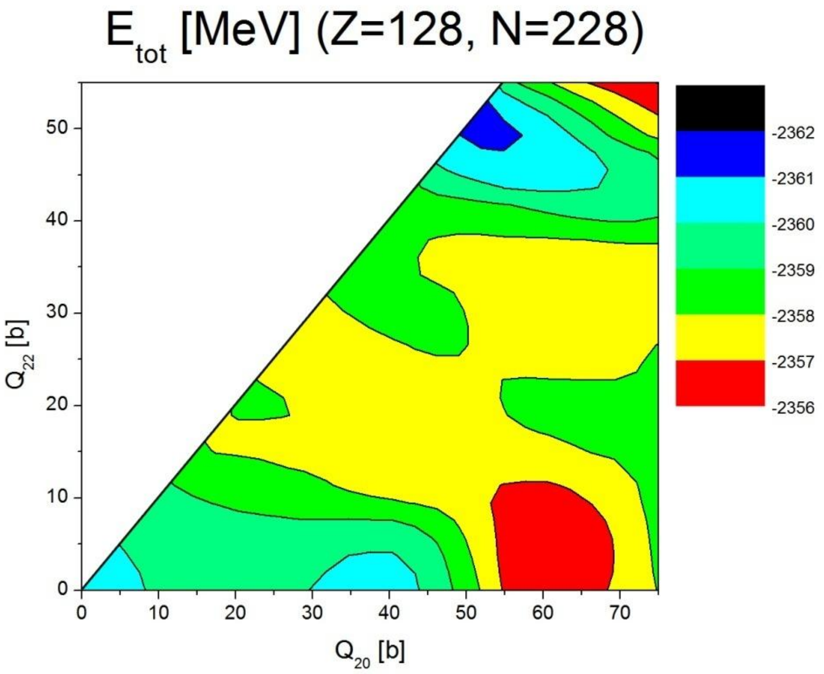
Shape at minimum: ---

Fission barrier: none

Micro-macro

Hartree-Fock-BCS





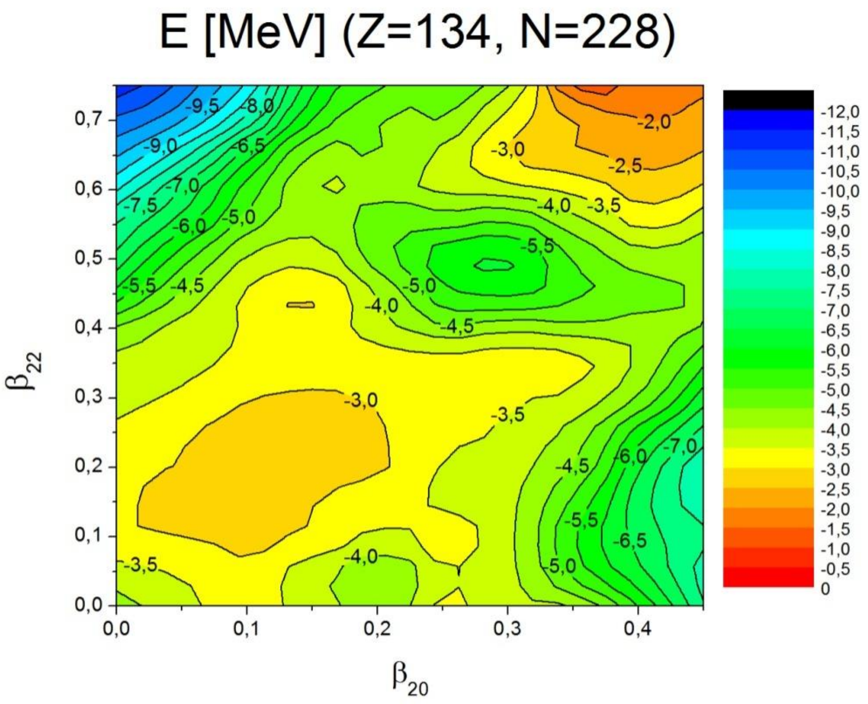
Shape at minimum: ---

Fission barrier: none

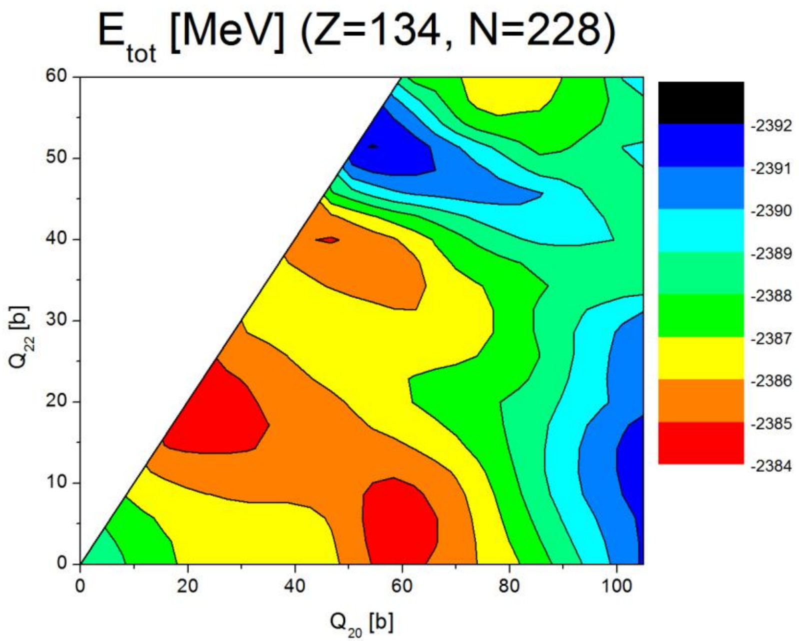
Shape at minimum: prolate/oblate

Fission barrier: 3.0 MeV / ?

Micro-macro



Hartree-Fock-BCS



Shape at minimum: oblate

Fission barrier: 2 MeV

Shape at minimum: spherical/oblate

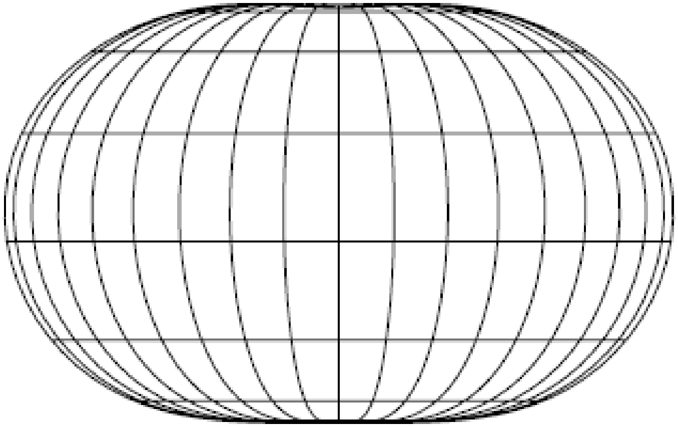
Fission barrier: 3.0/4.0 MeV

β-stable, $Q_\alpha \approx 10$ MeV

Conclusions

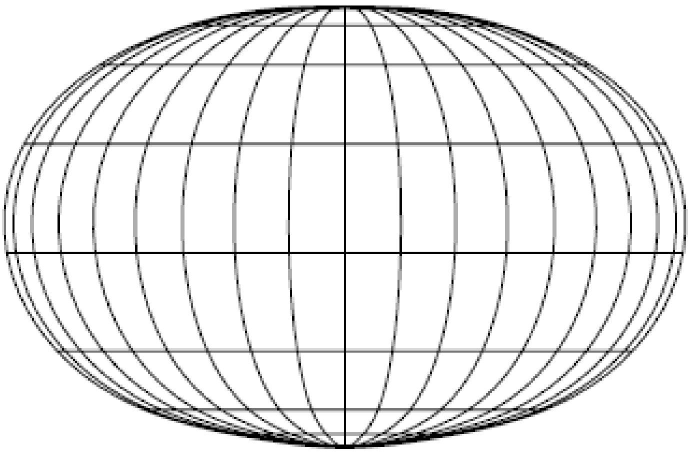
- Admitting nonaxial configurations is crucial for calculations of fission barriers,
- For Z=128, N≈180 4.5 MeV and 3.5 MeV minima occur in Hartree-Fock-BCS (spherical shape) and in micro-macro model (oblate shape), respectively. However these nuclei decay via α-emission,
- Both models give no minima for calculated nuclei with intermediate neutron numbers,
- For N=228 we found 3.0 MeV deep prolate and spherical minima in HFBCS model; additonally even lower oblate minimum appears, that needs to be further investigated. The latter occurs also in micro-macro model for Z=134 (2.0 MeV deep),
- Predictions of micro-macro model are rather pessimistic - no stability found for nuclei with Z>128, N>180,
- Results obtained from HFBCS model for Z=134, N=228 encourage further research of region with N≥228.

Thank you for your attention



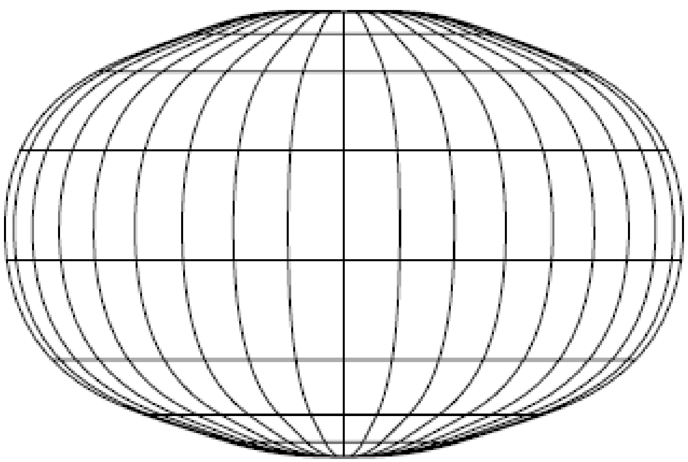
Z=120, N=166   beta2=-0.46

beta4=0



beta4=0.05,

Energy:



beta4=0.06, beta6=0.02, beta8=-0.02,

Energy: 1.76 MeV lower